MONTHLY VARIATION OF PRECIPITATION ECHO OCCURRANCES ACCROSS THE UNITED STATES

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ABSTRACT

The U.S. Weather Bureau's network of weather radar stations provides a source of hourly data which indicate the presence or absence of detectable precipitation in the atmosphere within range of the radar. This paper is concerned with variations of precipitation echo occurrences as reported on hourly RAREPS by six WSR-57 radars along a line running from New York City to Sacramento, Calif. When monthly percentage frequencies of precipitation echo occurrences were computed for each station and compared to variations of precipitation amount, it was evident that the influence of major topographic features may be detected. In addition, in the winter months, an indication of a station's relative continentality may be observed.

1. INTRODUCTION

The purpose of this study was to test the utilization of radar observations as a method of estimating monthly climatological variations of precipitation for a region. Hourly weather radar reports (RAREPS) from six U.S. Weather Bureau radars were scanned for instances of precipitation echoes. Percentage frequency of occurrence was computed and compared with variations in precipitation amount for similar time periods. Since the six radar stations selected extend across the United States from the Pacific coast to the Atlantic, it was possible to compare variations in precipitation echo occurrence to variations in precipitation amount for several different climatic regions. These varied from the subtropical "California" region through continental Midwest to the maritime region of the Atlantic coast.

Whenever precipitation echoes are observed on a previously clear radarscope, the fact is noted on a RAREP log (Form 610-3) with a code evaluation of the echo. As long as echoes are observed, hourly evaluations are recorded in chronological order. When the radarscope becomes clear of precipitation echoes, a contraction PPINE (no echoes) is logged, and the contraction is repeated every three hours as long as the scope remains clear.

This arrangement presents a yes or no condition with regard to the presence of precipitation echoes within range at each hour. In this study, hourly RAREPS are summed and divided by the total number of RAREPS to yield percentage frequency of occurrence by month for each radar station. Hourly RAREPS reporting equipment outages were not included.

2. SOURCES OF DATA

All radar stations used USWB WSR-57 radars which operate at 10-cm. wavelength, 500 kw. peak power output, a beam width of 1.8°, and a maximum range of 250 n. mi. Table 1 presents the sources of data.

The precipitation data used for comparison in table 2 were taken from long-term means published in the *Local Climatological Data* for each city.

It is important to realize that data presented here represent detectable precipitation in the atmosphere. It is possible to have precipitation present in an area, particularly at ranges greater than 100 mi., which is not detected because of (a) a radar reflectivity so low that the radar receiver cannot separate echo from background noise, or (b) a vertical extent not high enough to intercept the radar beam. Therefore, a record showing high percentage of echo occurrence is a combination of (1) high frequency of precipitation in the atmosphere, (2) precipitation echoes with strong reflectivity, and (3) precipitation with large vertical extent.

A recent study by Conte [1] indicates that even very light snow or drizzle can be detected 100 percent of the

TABLE 1.—*Stations and length of radar record*

Station	Period of Record	Total No. of Obs.
Sacramento, Calif.	3/60 to 6/62	19,606
Kansas City, Mo.	5/60 to 4/62	16,545
Des Moines, Iowa	6/60 to 5/62	16,846
St. Louis, Mo.	7/60 to 6/62	17,052
Cincinnati, Ohio	7/60 to 6/62	15,914
New York, N.Y.	3/61 to 10/62	12,747

TABLE 2.—*Monthly percentage frequency of echo occurrences (first line) and mean monthly precipitation amount. (second line). All hours.*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Sacramento	19	49	44	20	36	22	34	35	16	17	38	23	30
	3.64	3.00	2.60	1.49	0.69	0.13	0.01	0.01	0.24	0.79	1.83	3.60	18.03
Kansas City	25	36	50	51	54	78	74	67	55	41	23	29	49
	1.34	1.53	2.63	3.38	4.69	4.77	3.78	3.95	4.17	2.84	1.89	1.42	36.39
Des Moines	21	32	37	47	56	66	65	57	50	31	18	27	42
	1.15	1.16	1.92	2.73	4.29	4.71	3.39	3.61	3.41	2.39	1.60	1.19	31.55
St. Louis	24	37	47	47	57	64	62	65	50	41	27	30	46
	2.23	2.35	3.30	3.72	4.19	4.18	3.30	2.98	3.16	2.73	2.65	2.13	36.92
Cincinnati	40	43	48	55	60	60	67	68	52	43	40	48	52
	3.56	2.57	3.84	3.60	3.77	4.03	3.74	3.37	2.84	2.42	2.96	2.87	39.57
New York	57	55	34	58	57	60	70	59	49	50	59	46	55
	3.42	3.40	3.83	3.43	3.41	3.38	4.26	4.40	3.62	3.55	3.23	3.36	43.29

time out to 50 mi., and between 17 and 32 percent of the time out to 100 mi. He concludes that it would be possible for the WSR–57 radar to detect precipitation of any type or intensity to appreciably greater ranges if it were not for the limitation produced by the curvature of the earth which puts the target below the beam of the radar. He concludes that echo height becomes one of the most important factors as far as detectability is concerned for precipitation beyond 50 mi.

Wilson [2] has also noted the ability of the WSR–57 to detect practically all precipitation out to 100 mi. Therefore, it seems reasonable to assume that the frequency of precipitation echoes detected by the WSR–57 represents the frequency of precipitation occurrence in the atmosphere if variations in echo height are taken into account.

3. DISCUSSION

Table 2 matches climatic variations of precipitation amount throughout the year for each station with variation of precipitation echo occurrences as recorded by the weather radar at that station. Precipitation data are presented as inches of liquid water, and echo data are presented as percentage of hourly RAREPS with detectable precipitation echoes.

PRECIPITATION CLIMATOLOGY

Sacramento's precipitation data show an annual trend typical of a subtropical climate with winter rains and a very dry summer. Subtropical anticyclones develop over the oceans off west coasts of continents during summer thus keeping precipitation associated with cyclones and frontal activity at high latitudes and resulting in very dry summers. In winter, the anticyclones weaken and retreat southward allowing frontal activity to reach into middle latitudes. This kind of precipitation regime is sometimes classified the "Californian" [3] or "Mediterranean" type.

Data from Kansas City, Des Moines, and St. Louis are illustrative of a continental type of climate where summer months have a heavier precipitation than winter months. This is due partly to lower air temperature, which reduces the possible water vapor content, and which also favors development of anticyclones in winter. On the other hand, in summer moisture is readily available and convective activity is considerably greater. As distance increases eastward or southward away from the center of the continent (a) annual amount of precipitation increases and (b) the summer-winter disparity decreases. Thus, as the east coast of the United States is approached the continentality of the precipitation variation becomes less apparent at Cincinnati until at New York City transition is complete to a climate classified as maritime.

Table 2 represents a long-term presentation of precipitation variations. All stations, with the exception of Cincinnati, have 60 or more years of data included in the computation of the monthly and annual means. Cincinnati has slightly over 50 years.

PRECIPITATION ECHO OCCURRENCES

Monthly percentage frequencies of precipitation echo occurrences appear in table 2, and represent percentage of hourly observations during each month when echoes were detected. For example, the Kansas City radar detected precipitation echoes 50 percent of the time in March, or one hour out of every two. In June, Kansas City observed echoes 78 percent of the time, the highest percentage of all stations, coincident with the highest precipitation amount of all stations. This yearly trend of echo occurrences resembles the continentality apparent in precipitation data. Des Moines' data resemble Kansas City's with the exception that the lowest percentage appears in November instead of January.

Echo data from St. Louis and Cincinnati exhibit a trend similar to the transition from continental to maritime apparent in precipitation data except that echo maxima are shifted from June to August. New York City radar data show a maximum of echoes in July, a minimum in March, and 9 months out of 12 with more than 50 percent of hourly observations reporting precipitation echoes somewhere within range of the radar. Sacramento's radar data show little or no similarity to the climatic trend in the precipitation record. Normally, it would be expected that a minimum frequency of precipitation echoes would be observed in the summer months since Sacramento has very dry summers which typify a subtropical climate, but table 2 indicates a high occurrence of precipitation echoes during this season. A study [4] conducted by radar personnel at Sacramento during the summer months of 1960 and 1961 confirmed the presence of numerous convective echoes over the Sierra Nevada mountain range. It was found that 86 percent of all convective echoes which formed east of a line running down the Sacramento and San Joaquin Valleys occurred above the 7,000-ft. contour of the Sierra Nevada. Obviously, topography has a significant effect on summer rain shower activity in California that is not detected by the rain gage network at lower elevations.

Figure 1 is a plot of cumulative percentage frequency of hourly RAREPS with precipitation echoes by month

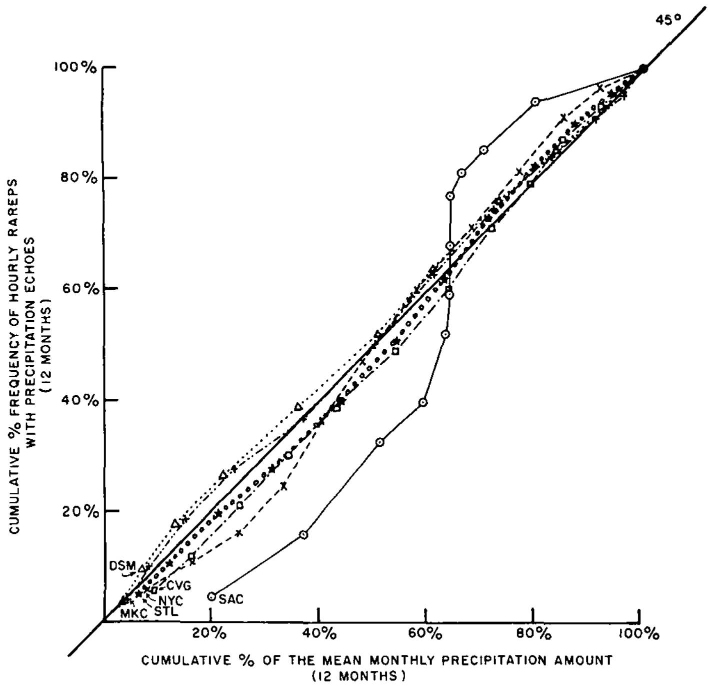

FIGURE 1.—Cumulative percentage frequency of hourly RAREPS with precipitation echoes, January to December, versus cumulative percentage frequency of mean monthly precipitation amount. SAC=Sacramento, MKC=Kansas City, DSM=Des Moines, STL=St. Louis, CVG=Cincinnati, and NYC=New York.

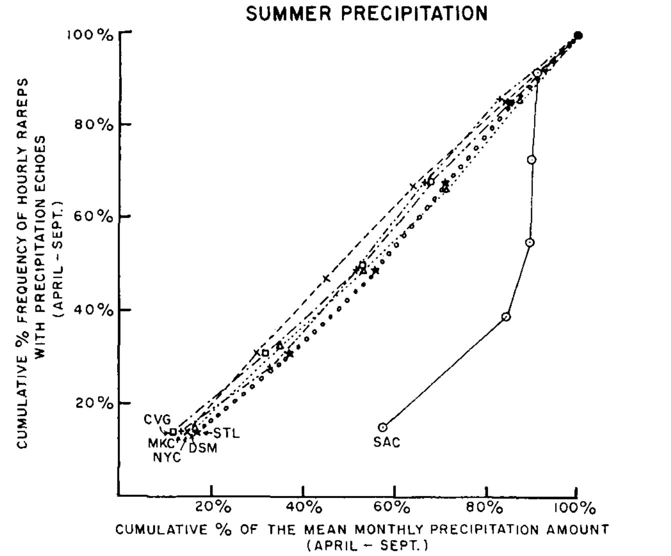

FIGURE 2.—Cumulative percentage frequency of hourly RAREPS with precipitation echoes, April to September, versus cumulative percentage frequency of mean monthly precipitation amount.

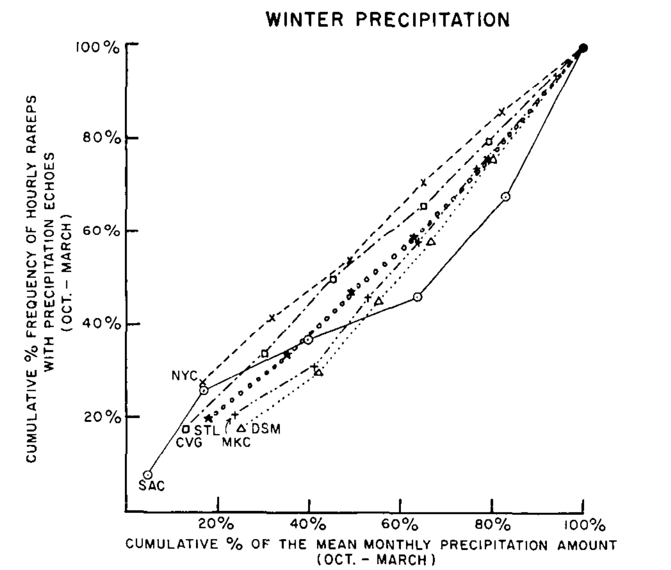

FIGURE 3.—Cumulative percentage frequency of hourly RAREPS with precipitation echoes, October to March, versus cumulative percentage frequency of mean monthly precipitation amount.

versus cumulative percentage frequency of mean monthly precipitation amount. With the exception of Sacramento, the data approximate a 45° line, tending to indicate a favorable comparison between the two sets of data. Sacramento's deviation may be explained by reference to table 1. Sacramento illustrates the dry summer-winter rain climate of the west coast, but radar, having surveillance over an area within 250 n. mi. detects summer convective activity over the Sierra Nevada range. Radar data do not indicate dry summer conditions; therefore, over the year January has only 5 percent of the total number of RAREPS with precipitation. Rain gage data, on the other hand, show that 20 percent of total precipitation for the year falls in January, wettest month in the rainy season.

Figures 2 and 3 are similar to figure 1 except that the year is divided into summer and winter halves. In figure 2, April through September, all stations, with the exception of Sacramento, fall very close to a 45° line. Occurrence of convective echoes over the Sierra Nevada when the valley region records no precipitation causes Sacramento's curve to fall out of line. An interesting feature of figure 3 is the spread of curves between Des Moines and New York City, when only the winter half of the year is considered. Disregarding Sacramento, the curves fall in a geographical sequence from west to east. New York has consistently a higher monthly cumulative percentage of echo occurrences than cumulative percentage of precipitation amounts. At Cincinnati the disparity is less, and at St. Louis the two values are almost equal. Kansas City has the difference reversed with precipitation percentage exceeding radar percentage, and Des Moines, the most continental of the five stations, has the greatest deviation from New York's curve. The reason for this disparity during winter seems to be the change in precipation detectability with climate. At New York, with a maritime climate, a higher portion of precipitation results from rain or rain shower activity which can be detected at longer ranges than snow because of higher vertical extent of echoes and stronger reflectivity. Local studies at Des Moines [5] have indicated the WSR–57 cannot always detect snow beyond 100 mi., and so the geographic shift revealed in figure 3 probably results from the variation of occurrence of snow in the atmosphere.

If the year is taken as a whole (fig. 1), a spread is again noticed in the winter months, but the opposite of what appeared in figure 3 and to a lesser degree. In the eastern part of the country there is an increase in precipitation echoes in summer that is proportionally greater than the increase in precipitation amount; therefore cumulative percentages of echoes would be less during the early part of the year than cumulative percentages of precipitation. At Kansas City and Des Moines the situation is reversed with precipitation amount increasing more rapidly from winter to summer.

4. SUMMARY

It is interesting to note how the monthly variations of percentage frequency of precipitation echo occurrences (2 yr.) resemble, with the exception of Sacramento, the mean monthly precipitation amount (>60 yr.). Moreover, there is a trend resembling continentality in the range of echo percentage for Kansas City, Des Moines, and St. Louis similar to that observed from rain gage records. Monthly variation of echo percentages becomes less extreme at Cincinnati, and at New York there is a trend resembling the maritime type of climate. Sacramento presents a monthly trend quite different from the typical subtropical regime indicated by the rain gage record, but this region also includes a major topography feature of the Sierra Nevada mountains which, judging from the frequency of echo occurrences, do not have the totally dry summers the valley stations experience. Therefore, a comparison of radar versus precipitation data (fig. 1) serves to detect any topographic influences which might change or modify the precipitation regime. In addition, in the winter months (fig. 2) an indication of a station's relative continentality may be observed.

Since the WSR–57 weather radars went into operation in 1960 or later, the data obtained are limited therefore to one or two years of record. Additional data will modify these results; however it is apparent that radar does present a logical and valuable pattern when viewed against established long-term precipitation records. These data may prove very useful in future climatic studies.

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[*Received June 14, 1963; revised November 5, 1963*]